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Full Length Research Paper

The influence of market barriers and farm income risk on non-farm income diversification

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Empirical evidence shows that non-farm income diversification is associated with higher welfare among farm households. However, most studies have ignored market barriers and farm income risk in explaining income diversification behaviour. This study develops a theoretical framework that includes both market barriers and farm income risk, in addition to other factors, in explaining income diversification behaviour. The theoretical framework is used to empirically test the hypotheses that: market barriers reduce the intensity of non-farm income diversification; and farm income risk increases the intensity of non-farm income diversification. The results confirm the hypotheses, suggesting that market barriers and farm income risk are key factors in explaining income diversification behaviour of farm households. Future studies should therefore, consider the two factors in the analysis of income diversification behaviour.

Key words: Market barriers, farm income risk, income diversification.

INTRODUCTION

There is emerging evidence that non-farm income diversification is associated with higher income and food consumption, as well as more stable income and consumption over time (Reardon et al., 1992; Dercon and Krishnan, 1996; Reardon, 1997; Reardon et al., 1998; Barrett et al., 2000; Block and Webb, 2001; Canagarajah et al., 2001). Non-farm income sources are also effective in combating poverty and inequality (De Janvry and Sadoulet, 2001). As a result, most studies have investigated the factors that influence non-farm income diversification, especially in developing countries (Ellis, 2000; Barrett et al., 2001a; Abdulai and CroleRees, 2001; Woldenhanna and Oskam, 2001; De Janvry and Sadoulet, 2001; Reardon et al., 2007). These factors can be grouped into 5 categories, namely:

1. Individual and household characteristics;
2. Farm characteristics;
3. Locational factors;
4. Barriers to income diversification; and
5. Risk factors.

Individual and household characteristics comprise age, gender, education, marital status and household size among other characteristics (Reardon, 1997; De Janvry and Sadoulet, 2001; Deininger and Olinto, 2001; Lanjouw et al., 2001; Abdulai and CroleRees, 2001; Escobal, 2001; Woldenhanna and Oskam, 2001; Barrett et al., 2001a; Yunez-Naude and Taylor, 2001; Wouterse and Taylor, 2008). Farm characteristics consist of characteristics such as amount of land cultivated, number of crops grown, value of farm implements, membership in a farm organization and access to agricultural extension (Woldenhanna and Oskam, 2001; De Janvry and Sadoulet, 2001). Locational factors may include the nature of the roads, availability of electricity and distance from towns (Lanjouw et al., 2001; Barrett et al., 2001b; De Janvry and Sadoulet, 2001; Escobal, 2001; Joshi et al., 2002; Winters et al., 2002). Barriers to income diversification may consist of factors such as inaccessibility to credit and market information, which may discourage non-farm income diversification (Escobal, 2001; Winters et al., 2002; Schwarze and Zeller, 2005). Risk factors capture the impact of the variability of returns from various activities (Mishra and Goodwin, 1997; Abdulai and CroleRees, 2001).

Although most of the studies in the non-farm income diversification literature have included individual and household characteristics, farm characteristics and locational factors in assessing income diversification behaviour, only a few studies have included market barriers and farm income risk. As a result, the influences of market barriers and farm income risk on non-farm income diversification have been inadequately researched. In addition, the models developed to explain non-farm income diversification behaviour have ignored the joint influence of market barriers and farm income risk. Based on the mean-variance utility approach, this study develops a theoretical framework that includes both market barriers and farm income risk, in addition to other factors (household characteristics, farm characteristics and locational factors) in explaining income diversification behaviour. The theoretical framework is used to empirically test the hypotheses that:

1. Market barriers reduce the intensity of non-farm income diversification; and
2. Farm income risk increases the intensity of non-farm income diversification.

Cross-sectional data collected in 2004 in the semi-arid areas of Eastern Kenya is used to test the hypotheses. The Kenyan data is chosen for the tests because of its availability.

MATERIALS AND METHODS

Theoretical framework

The theoretical model is based on the following assumptions: a household as the unit of analysis; mean-variance utility function; two source of income, farm and non-farm; farming comprises crop and livestock production; farm production function is quasi-concave and twice differentiable; constant absolute risk aversion; fixed leisure; income risk comes from farming, while non-farm work is not risky; and farm income risk comes from fluctuations in weather.

In terms of the model structure, Let M_{farm}, $M_{nonfarm}$ and M_{total} represent farm income, non-farm income and total household income, respectively, with $\overline{M}_{farm}$ and $\overline{M}_{nonfarm}$ denoting the expected farm and non-farm incomes. Also, let R be the absolute risk aversion coefficient and $\sigma^2_{M_{farm}}$ be the variance of farm income. The Mean-Variance utility function [$EU(M)$] is specified as:

$$Max \quad EU(M) = \overline{M}_{farm} + \overline{M}_{nonfarm} - \frac{R}{2}\sigma^2_{M_{farm}} \qquad (1)$$

Now, let the amount of time spent by a household in leisure, farming, non-farm work, and the total time available for work, be represented by $\overline{T}_{leis}$, T_{farm}, $T_{nonfarm}$ and T_A, respectively.

Likewise, let Q be farm output, P_q be price of farm output, K be cost per unit farm output, e_{farm} be the random variable for weather, $\sigma^2_{e_{farm}}$ be the variance of farm output, W be non-farm wage and θ be the proportion of time spent in non-farm work (the choice variable). Also, denote household characteristics, farm work characteristics and locational factors by Z, F_C and L_C, respectively. In addition, let B represent the proportion of non-farm income lost as a result of barriers to income diversification. Equation (1) can be expanded as:

$$\underset{\theta}{Max} \; EU(M) = (P_q - K)Q((1-\theta)T_A; Z, F_C, L_C) + W\theta T_A(1-B) - \frac{R}{2}\left((P_q - K)^2 Q^2 \sigma^2_{e_{farm}}\right) \qquad (2a)$$

Where,

$$0 \le \theta < 1; \;\; 0 \le B \le 1 \qquad (2b)$$

$$T = T_A + \overline{T}_{leis} \qquad (2c)$$

$$T_{farm} = (1-\theta)T_A; \quad T_{nonfarm} = \theta T_A \qquad (2d)$$

$$M_{farm} = (P_q - K)Q((1-\theta)T_A; Z, F_C, L_C)(1 + e_{farm}) \qquad (2e)$$

$$E(M_{farm}) = \overline{M}_{farm} = (P_q - K)Q((1-\theta)T_A; Z, F_C, L_C) \qquad (2f)$$

$$E(M_{nonfarm}) = \overline{M}_{nonfarm} = W\theta T_A(1-B) \qquad (2g)$$

$$\sigma^2_{M_{farm}} = (P_q - K)^2 Q^2 \sigma^2_{e_{farm}} \qquad (2h)$$

$$Ee_{farm} = 0 \qquad (2i)$$

Differentiating Equation (2a) with respect to θ gives the first order conditions (F.O.C.s) as:

$$\frac{dEU(M)}{d\theta} = -(P_q - K)\frac{dQ(.)}{dT_{farm}}T_A + WT_A(1-B) + R(P_q - K)^2 Q(.)\frac{dQ(.)}{dT_{farm}}T_A\sigma^2_{e_{farm}} \le 0 \qquad (3a)$$

$$\theta * \frac{dEU(M)}{d\theta} = 0 \quad \text{(3b)}$$

The second order condition (S.O.C.) is given as:

$$\frac{d^2 EU(M)}{d\theta^2} = H = (P_q - K)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2 - R(P_q - K)^2\left(\frac{dQ(.)}{dT_{farm}}\right)^2 T_A^2 \sigma_{e_{farm}}^2$$
$$- R(P_q - K)^2 Q(.)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2\sigma_{e_{farm}}^2 < 0 \quad \text{(4)}$$

Let the expected utility as a result of specializing in farm work be $EU(M)_{spec}$. Similarly, let the expected utility as a result of diversifying income into non-farm work be $EU(M)_{div}$. A utility maximizing household will only diversify income into non-farm work (that is, $\theta > 0$) if $EU(M)_{div} > U(M)_{spec}$. If the household decides to diversify income, then from the F.O.C.s, the optimal proportion of time spent in non-farm work is given as:

$$\theta^* = \theta^*((P_q - K), B, \sigma_{e_{farm}}^2; Z, F_C, L_C) \quad \text{(5)}$$

Where $P_q - K$ represents the farm profit per unit output. Now substitute θ^* in the farm income, non-farm income and total household income functions and denote $P_q - K$ as π_q. The optimal income functions are gives as:

$$\frac{d\lambda^*}{d\theta^*} = \frac{M_{Total}^*(.)\frac{dM_{nonfarm}^*(.)}{d\theta^*} - M_{nonfarm}^*(.)\frac{dM_{Total}^*(.)}{d\theta^*}}{\left[M_{Total}^*(.)\right]^2} > 0 \quad \text{(9a)}$$

$$M_{farm}^* = M_{farm}^*\left(\theta^*(\pi_q, B, \sigma_{e_{farm}}^2; Z, F_C, L_C)\right) \quad \text{(6a)}$$

$$M_{nonfarm}^* = M_{nonfarm}^*\left(\theta^*(\pi_q, B, \sigma_{e_{farm}}^2; Z, F_C, L_C)\right) \quad \text{(6b)}$$

$$M_{total}^* = M_{total}^*\left(\theta^*(\pi_q, B, \sigma_{e_{farm}}^2; Z, F_C, L_C)\right) \quad \text{(6c)}$$

The intensity of non-farm income diversification is defined as the proportion of non-farm income in total income (λ). The optimum λ (that is, λ^*) is specified as:

$$\lambda^* = \frac{M_{nonfarm}^*(\theta^*)}{M_{Total}^*(\theta^*)} = \lambda^*\left(\theta^*(\pi_q, B, \sigma_{e_{farm}}^2; Z, F_C, L_C)\right) \quad \text{(7)}$$

Comparative statics is undertaken to obtain $\partial\lambda^*/\partial B$ and $\partial\lambda^*/\partial\sigma_{e_{farm}}^2$, assuming interior solutions for θ. Using chain rule, the two derivatives can be specified as:

$$\frac{\partial\lambda^*}{\partial B} = \frac{d\lambda^*}{d\theta^*} * \frac{\partial\theta^*}{\partial B} \quad \text{(8a)}$$

$$\frac{\partial\lambda^*}{\partial\sigma_{e_{farm}}^2} = \frac{d\lambda^*}{d\theta^*} * \frac{\partial\theta^*}{\partial\sigma_{e_{farm}}^2} \quad \text{(8b)}$$

Deriving $d\lambda^*/d\theta^*$, $\partial\theta^*/\partial B$ and $\partial\theta^*/\partial\sigma_{e_{farm}}^2$ gives[1]:

$$\frac{\partial\theta^*}{\partial B} = \frac{WT_A}{H} < 0 \quad \text{(9b)}$$

$$\frac{\partial\theta^*}{\partial\sigma_{e_{farm}}^2} = \left(-R(\pi_q)^2 Q(.)\frac{dQ(.)}{dT_{farm}}T_A\right)\frac{1}{H} > 0 \text{ if } R > 0 \quad \text{(9c)}$$

[1] See the technical appendix for derivations of $\partial\theta^*/\partial B$ and $\partial\theta^*/\partial\sigma_{e_{farm}}^2$.

Substituting Equations (9a-c) in Equations (8a) and (8b) gives:

$$\frac{\partial \lambda^*}{\partial B} = \frac{M^*_{Total}(.)\frac{dM^*_{nonfarm}(.)}{d\theta^*} - M^*_{nonfarm}(.)\frac{dM^*_{Total}(.)}{d\theta^*}}{\left[M^*_{Total}(.)\right]^2} * \frac{WT_A}{H} < 0 \qquad (10a)$$

$$\frac{\partial \lambda^*}{\partial \sigma^2_{e_{farm}}} = \frac{M^*_{Total}(.)\frac{dM^*_{nonfarm}(.)}{d\theta^*} - M^*_{nonfarm}(.)\frac{dM^*_{Total}(.)}{d\theta^*}}{\left[M^*_{Total}(.)\right]^2} * \frac{-R(\pi_q)^2 Q(.)\frac{dQ(.)}{dT_{farm}}T_A}{H} > 0 \text{ if } R > 0 \qquad (10b)$$

In sum, the study tests the hypotheses that:

1. Market barriers (measured by inaccessibility to credit) reduce the intensity of non-farm income diversification (Equation 10a); and
2. Farm income risk (measured by the coefficient of variation of farm income) increases the intensity of non-farm income diversification (Equation 10b).

Econometric model specification and estimation

Following Mishra and Goodwin (1997), a Two-Limit Tobit regression model[2] was used to estimate the determinants of the intensity of non-farm income diversification (Equation 7). The Two-Limit Tobit model is specified as follows:

$$\lambda = \begin{cases} \lambda^* = X\beta + \varepsilon \text{ if } EU(M)_{div} > U(M)_{spec}; 0 < \lambda^* < 1 \\ 0 \quad \text{if } EU(M)_{div} \leq U(M)_{spec} \end{cases} \qquad (11)$$

Where λ is the observed proportion of non-farm income in total income, β are the parameter estimates and ε is the error term.

In addition, X comprises farm profit per unit output (π_q), household characteristics (Z), farm work characteristics (F_C), locational factors (L_C), barriers to participation in non-farm work (B) and farm income risk ($\sigma^2_{e_{farm}}$). Since there is no data on farm profit per unit output, a perception variable on the cost of farm inputs is used as a proxy for farm profit per unit output. Household characteristics are captured by the age of the household head, age squared, gender of the household head, education (that is, primary or secondary education) and family size. Farm characteristics are captured by farm size, value of farm implements, access to agricultural extension and membership of a farmers' group. Locational factors are captured by dummy variables for Machakos and Makueni districts. Barriers to income diversification are captured by inaccessibility to credit. Farm income risk is captured by the coefficient of variation of farm income, measured in terms of the standard deviation of two season (short and long rain) farm income expressed as a percentage of the mean seasonal farm income. In addition to the hypotheses on the influence of barriers to income diversification and farm income risk, it is expected that education, family size, value of farm implements and the locational dummies positively influence the intensity of income diversification, while perception of the cost of farm inputs, farm size, access to agricultural extension and membership of a farmer's group negatively influence the intensity of income diversification. The directions of influence of age and gender cannot be anticipated *a priori*.

Data

The data was collected from 228 farmers in the semi-arid areas of Eastern Kenya, by means of semi-structured questionnaires. The survey was undertaken jointly by the Kenya Agricultural Research Institute (KARI-Katumani) and the University of Nairobi, under the collaboration on agricultural/resource modeling and applications in semi-arid Kenya (CAMASAK) project. The area covered was a catchment of about 5000 km^2 that encompasses three districts, namely: 1) Machakos, 2) Makueni and 3) Kitui. Machakos district houses Machakos town which is a capital town of the Eastern province. Of the three districts, Machakos district is the most developed district in terms of infrastructure and other social amenities, followed by Makueni and Kitui in that order. According to the 1999 Kenyan census, Machakos district had a population of 906,644; Makueni district had a population of 771,545, while Kitui district had a population of 515,422.

Geographical information system (GIS) guided random sampling procedure was used to select farmers to be interviewed. Using this procedure, 30 blocks (1 km2 each) were randomly selected from the catchment. Farmers were then randomly interviewed in these blocks. The survey was based on long and short-rain seasons of the year 2003. Questions asked include: household characteristics, farm characteristics, locational factors, marketing and institutional support and non-farm income diversification. A summary of descriptive statistics of the variables is given in Table 1.

RESULTS AND DISCUSSION

Table 2 reports the parameter estimates and marginal effects for the Two-Limit Tobit model of the intensity of non-farm income diversification. The model fit is satisfactory. This evaluation is based on the likelihood ratio statistic which is statistically significant at the 1% level. This means that all 15 variables included in the model are jointly able to explain the variations in the

[2]See McMillen and McDonald (1990) for a more detailed description of the Two-Limit Tobit model.

Table 1. Variable definitions and summary statistics.

Variable	Definition	Mean	Std. deviation
Income diversification			
Total income	Annual household total income in Kenyan Shillings (Kshs)	37.532	63.041
Farm income	Annual household farm income in Kshs	13.251	17.815
Non-farm income	Annual household non-farm income in Kshs	24.282	58.018
Income diversification intensity	Proportion of non-farm income in total income	0.4260	0.3497
Farm profitability			
Perception of the cost of farm inputs	Dummy variable; 1= inexpensive, 0 = expensive	0.899	0.302
Household characteristics			
Age of household head	Continuous variable; in years	48.3904	14.7476
Gender	Dummy variable; 1 = male, 0 = female	0.6974	0.4604
Education			
Primary	Dummy variable; 1= primary education, 0=otherwise	0.5658	0.4967
Secondary	Dummy variable; 1= secondary and above, 0=otherwise	0.2544	0.4365
Family size	Continuous variable; number of family members	5.4518	3.1219
Farm characteristics			
Farm size	Continuous variable; size of farm in acres	3.9526	3.2830
Value of farm implements	Continuous variable; value of farm implements in '000' Kshs	7.3135	10.3009
Access to agricultural extension	Dummy variable; 1= if received extension, 0=otherwise	0.1886	0.3920
Membership of farmers' group	Dummy variable; 1= if member, 0=otherwise	0.3947	0.4899
Locational factors			
Machakos district	Dummy variable; 1= if in Machakos district, 0=otherwise	0.5921	0.4925
Makueni district	Dummy variable; 1= if in Makueni district, 0=otherwise	0.3772	0.4858
Barriers to income diversification			
Inaccessibility to credit	Dummy variable; 1= if no access to credit, 0=otherwise	0.8158	0.3885
Farm income risk			
Coefficient of variation of farm income	Continuous variable; coefficient of variation of farm income; in percentage	48.4153	32.3122

proportion of non-farm income. All the parameter estimates and marginal effects have expected signs. The results show that 9 out of 15 variables are statistically significant at the 10% level or better. Secondary education, family size, location (district) dummies and coefficient of variation of farm income positively and significantly influence the proportion of non-farm income. This means that household heads that have at least secondary education, have larger family sizes, live in Machakos or Makueni districts and experience a higher variation in farm income have a higher proportion of non-farm income. These findings are consistent with those of previous studies such as Mishra and Goodwin (1997), Canagarajah et al. (2001), and Wouterse and Taylor (2008). The results also indicate that farm size, access to agricultural extension, membership of a farmers' group and inaccessibility to credit negatively and significantly influence the proportion of non-farm income. This means that households with larger farms, who have access to agricultural extension, are members of a farmers' group and do not have access to credit, have a lower proportion of non-farm income. The negative influence of farm size on non-farm income diversification is consistent with past studies such as Woldenhanna and Oskam (2001), De Janvry and Sadoulet (2001), Yunez-Naude and Taylor (2001), Adams (2002) and Kuiper et al. (2006). Similarly, the negative influence of inaccessibility to credit is consistent with the findings of Schwarze and Zeller (2005).

The results confirm our first hypothesis that market barriers reduce the intensity of non-farm income diversify-cation. This interpretation is based on the negative

Table 2. Two-Limit Tobit regression results for the intensity of non-farm income diversification.

Variable	Parameter estimate	Marginal effect
Farm profitability		
Perception of the cost of farm inputs (1 = inexpensive)	-0.1188 (-1.2023)	-0.0869 (-1.1910)
Household characteristics		
Age of household head	0.0014 (0.1024)	0.0010 (0.1024)
Age squared	0.00004 (0.3194)	0.00003 (0.3178)
Gender (1 = male)	-0.0897 (-1.2492)	-0.0648 (-1.2395)
Education		
Primary	0.0765 (0.7417)	0.0547 (0.7429)
Secondary	0.2157* (1.6673)	0.1574* (1.6454)
Family size	0.0200* (1.7014)	0.0143* (1.7106)
Farm characteristics		
Farm size	-0.0208* (-1.6871)	-0.0149* (-1.6800)
Value of farm implements	0.0021 (0.5403)	0.0015 (0.5399)
Access to agricultural extension	-0.1929** (-2.0720)	-0.1327** (-2.1908)
Membership of farmers' group	-0.1227* (-1.8054)	-0.0873* (-1.8169)
Locational factors		
Machakos district	0.4106* (1.7753)	0.2823* (1.8993)
Makueni district	0.5503** (2.3625)	0.3900** (2.5167)
Barriers to income diversification		
Inaccessibility to credit	-0.1892** (-2.2714)	-0.1386** (-2.2528)
Farm income risk		
Coefficient of variation of farm income	0.0019** (2.0161)	0.0014** (2.0109)
Constant	-0.1026 (-0.2168)	
Sigma	0.4365*** (18.4707)	
Model statistics		
Number of observations	228	
Likelihood ratio test (df=15)	35.3350***	

* **, **, * indicates significance at 1, 5 and 10% levels, respectively; t-values in parenthesis. Dependent variable is proportion of non-farm income in total income.

and significant influence of inaccessibility to credit on the proportion of non-farm income. In addition, the marginal effect shows that inaccessibility to credit reduces the proportion of non-farm income by 14%. The results also confirm the second hypothesis that farm income risk increases the intensity of non-farm income diversification. This is based on the positive and significant influence of coefficient of variation of farm income on the proportion of non-farm income. The marginal effect shows that a 10% increase in the coefficient of variation of farm income results into a 1.4% increase in the proportion of non-farm income. The confirmation of the hypotheses on market barriers and farm income risk shows that these factors, which have generally been ignored by past studies, are key in explaining income diversification behaviour of farm households.

CONCLUSION AND RECOMMENDATIONS

Empirical evidence shows that non-farm income diversification is associated with higher welfare among farm households. However, most studies have ignored market barriers and farm income risk in explaining income diversification behaviour. The present study develops a theoretical framework that includes both market barriers and farm income risk, in addition to other factors, in explaining income diversification behaviour. The theoretical framework is used to empirically test the hypotheses that:

1. Market barriers reduce the intensity of non-farm income diversification; and
2. Farm income risk increases the intensity of non-farm income diversification.

The Two-Limit Tobit regression results, confirm the hypothesis that market barriers reduce the intensity of non-farm income diversification. This interpretation is based on the negative and significant influence of inaccessibility to credit on the proportion of non-farm income. Similarly, the regression results confirm the hypothesis that farm income risk increases the intensity of non-farm income diversification. This is based on the positive and significant influence of the coefficient of variation of farm income on the proportion of non-farm income. These results show that market barriers and farm income risk are key factors in explaining income diversification behaviour of farm households. Future studies should, therefore, consider these two factors in the analysis of income diversification behaviour.

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APPENDIX

The comparative statics are undertaken assuming interior solutions for θ. In order to derive $\partial\theta^* / \partial B$, totally differentiate the F.O.C. (Equation 3a) with respect to B, which gives:

$$(P_q - K)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2\frac{\partial\theta^*}{\partial B} - WT_A - R(P_q - K)^2\left(\frac{dQ(.)}{dT_{farm}}\right)^2 T_A^2\sigma_{e_{farm}}^2\frac{\partial\theta^*}{\partial B}$$
$$-R(P_q - K)^2 Q(.)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2\sigma_{e_{farm}}^2\frac{\partial\theta^*}{\partial B} = 0 \quad \text{(A1)}$$

And hence:

$$\frac{\partial\theta^*}{\partial B} = \frac{WT_A}{(P_q - K)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2 - R(P_q - K)^2\left(\frac{dQ(.)}{dT_{farm}}\right)^2 T_A^2\sigma_{e_{farm}}^2 - R(P_q - K)^2 Q(.)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2\sigma_{e_{farm}}^2} \quad \text{(A2)}$$

$$= \frac{WT_A}{H} < 0 \quad \text{(A3)}$$

In order to derive $\partial\theta^* / \partial\sigma_{e_{farm}}^2$, totally differentiate the F.O.C. (Equation 3a) with respect $\sigma_{e_{farm}}^2$ which gives:

$$(P_q - K)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2\frac{\partial\theta^*}{\partial\sigma_{e_{farm}}^2} - R(P_q - K)^2\left(\frac{dQ(.)}{dT_{farm}}\right)^2 T_A^2\sigma_{e_{farm}}^2\frac{\partial\theta^*}{\partial\sigma_{e_{farm}}^2}$$
$$-R(P_q - K)^2 Q(.)\frac{d^2Q(.)}{dT_{farm}^2}T_A^2\sigma_{e_{farm}}^2\frac{\partial\theta^*}{\partial\sigma_{e_{farm}}^2} + R(P_q - K)^2 Q(.)\frac{dQ(.)}{dT_{farm}}T_A = 0 \quad \text{(A4)}$$

And hence:

$$\frac{\partial\theta^*}{\partial\sigma_{e_{farm}}^2} = \frac{-R(P_q - K)^2 Q(.)\frac{dQ(.)}{dT_{farm}}T_A}{H} = \frac{-R(\pi_q)^2 Q(.)\frac{dQ(.)}{dT_{farm}}T_A}{H} > 0 \text{ if } R > 0 \quad \text{(A5).}$$